Reducing Bell Pepper Bruising during Postharvest Handling

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SUMMARY. The tender skin of bell peppers (*Capsicum annuum* L.) covers a crisp, fragile flesh that is easily bruised, cracked or crushed. During commercial harvest and postharvest handling operations, bell peppers undergo several transfers, each of which has the potential for causing mechanical injury to the peppers. These mechanical injuries include abrasions, cuts, punctures, and bruises, which affect the market grade and reduce pepper quality and subsequent life. Previous research on handling fresh vegetables and fruits has shown that the instrumented sphere (IS) is a tool that can help identify potentially damaging impacts during harvest and postharvest handling operations. For the study reported, the IS was used to evaluate the damage potential for peppers being hand harvested, and for peppers on a packing line. Studies in the field attempted to duplicate how pickers harvest peppers into pails and then empty them into empty wooden pallet bins. For the packing line evaluated, the diverging roll-sizer had the greatest potential for damage. Adding cushioning to hard surfaces and removing the metal support from under the cross-conveyor would help to reduce pepper damage. Cushioned ramps, and hanging flaps or curtains should be used to help reduce

acceleration and drop height between pieces of equipment. All locations should be cushioned where peppers impact a hard surface, and drop height should be limited to 3 inches (8 cm) on a hard surface and 8 inches (20 cm) on a cushioned surface. The speed of all components in the system should be checked and adjusted to achieve full line flow of peppers without causing bruising. Workers must receive instruction on the significance of bruising during the harvest and postharvest operations.

Whether bell peppers are intended for fresh market or processing, harvested by hand or by mechanical harvester, there are several transfers during commercial harvesting and postharvest handling operations. Each transfer has potential for causing mechanical injury (damage) to the peppers. These mechanical injuries include abrasions, cuts, punctures, and bruises. Mechanical injuries are defects that affect the market grade of the peppers and may reduce pepper quality and subsequent life. Mechanical injury and damage result when the pepper hits a hard surface. If that surface has sharp corners or edges, a surface cut or puncture can occur. If that surface is rough, abrasion or indentation may occur.

Damage may be observed as a soft spot on the surface of the pepper (bruising). However, if the pepper is cut open, cracks will often be evident in the interior lobes and flesh. These soft spots and areas of flesh injury facilitate decay of peppers.

When an object such as a pepper falls and impacts a surface, it slows down, compresses and stops, then begins to rebound. The amount of energy in the falling object is related to its weight and the distance it falls. During the impact, this energy is either absorbed by the surface of the fruit, or it is used in creating rebound or bounce of the object off the surface. With vegetables and fruits, there is little energy returned for rebound. When damage occurs, most of the impact energy is absorbed by the produce. Cushioning materials reduce damage by absorbing some of the impact energy, spreading the impact over a larger area, and spreading the impact and rebound over a longer time period.

Impacts likely to occur as peppers are harvested, handled, graded, and

packed can be measured using a portable sensor, data logger device called an instrumented sphere (IS) (Techmark, Inc., Lansing Mich.). The IS was developed by USDA and Michigan State University researchers (Tennes et al., 1990; Zapp et al., 1990) as a tool for quantifying the impacts that occur in handling equipment. The IS is a 3.5 inch (9 cm) diam, 12.4 oz (350 g) maximum impact data acquisition unit that records acceleration over time. The software communication package can interpret this data to determine the dynamic impact characteristics, including magnitude, duration, and time of impact. Impacts measured by the IS are defined by peak acceleration (the height of the acceleration curve) and velocity change (the area under the acceleration curve). Impacts on hard surfaces are characterized by a large peak acceleration and a small velocity change. Impacts from the same height on cushioned or soft surfaces show a smaller peak acceleration and longer time duration, as illustrated in Fig. 1. For any set of impacts, a greater drop height will result in a larger peak acceleration. Similarly, better cushioning will result in a larger velocity change.

The objectives of this study were to investigate the causes and practices in the field and in packing lines that contribute to bruising of bell peppers and to evaluate a bell pepper packing line for potentially damaging impacts. The paper will conclude with a discus-

Fig. 1. Typical impact curves for an object impacting a firm (hard) surface and a soft (cushioned) surface from the same drop height; hard surface impacts are characterized by larger peaks and shorter time durations; soft surface impacts are characterized by lower peaks and longer time durations.

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Fig. 2. Simulating picking bell peppers by hand into a 5-gal (18.9-L) pail; the steel line is for the instrumented sphere (IS) dropped onto a steel surface from a variety of heights (Brook, 1993); the cushioned line is for the IS dropped onto a cushioned surface from a variety of heights (Brook, 1993); the pepper damage threshold line was estimated from University of Florida data (Sargent et al., 1991).

sion of related issues that affect bell pepper bruising, and will present a set of recommendations for reducing bell pepper bruising.

Materials and methods

The following transfer points were investigated: 1) field picking transfer into empty and partially filled plastic picking pail, 2) emptying picking pail into empty and partially filled wooden field bin, and 3) movements through grading line at packing shed. Tests were conducted in a Michigan pepper field to measure impacts that occur during hand harvest of bell peppers using a plastic pail emptied into a wooden pallet bin. Bell pepper grading line transfers were evaluated at a packing shed in central Michigan.

For the field picking transfer, the IS was placed into a 5-gal (18.9-L) plastic pail, as if it were a pepper that had been handpicked. The pail was either empty, contained one layer, or was half-full of peppers. The drop height was ≈ 14 , 10.5, and 7 inches

(35, 27, and 17 cm), respectively.

The pallet bin test emptied a pail of bell peppers into a wooden field bin. The IS was placed in the center of the pail bottom and the pail was then filled half full. The pail was dumped over the top edge of the pallet bin.

The grading line tests were conducted in a pepper packing house. Several points where the peppers transferred from one piece of equipment to another were identified: onto the washer rolls, inspection rollers, waxer, sizer, and cross conveyor for graded peppers. These transfers involved either a drop or a roll down a ramp. The grading line test was conducted with the line stationary and no peppers present. The presence of peppers would likely lessen the impacts because of pepper-against-pepper cushioning, as has been previously observed by Sargent et al., (1992).

A separate set of tests was conducted to drop the IS from three different heights onto bell peppers held stationary. The bell peppers were held by hand such that the falling IS impacted directly on the shoulder of the peppers. The IS was dropped from heights of ≈ 4 , 6, and 8 inches (10, 15, and 20 cm). The impact locations on the peppers were then evaluated for the degree and type of bruising that occurred.

The data for the pepper damage threshold used in this report was developed by Sargent et al. (1991). The damage threshold indicates impacts

which are potentially damaging. An impact registered below the pepper damage threshold would most likely not cause a bruise on a bell pepper. The steel reference line in Figs. 2 to 4 is impact data when the IS was dropped on a steel (hard) surface; the cushioned reference line is impact data plotted when the IS was dropped onto a cushion material (Brook, 1993).

Results and discussion

The results of picking transfers into picking pails are illustrated in Fig. 2. Note that the data marked "X" (into the empty pail) were generally higher than most of the other data points because of the hard surfaces and greater drop distances.

When comparing the recorded impacts to the pepper damage threshold, it appears that the typical hand picking operation will not likely result in pepper bruising. Many of the impacts are to the right of the cushioned line (large velocity change), indicating that very soft impacts were involved.

The results of transferring peppers into wooden bins are illustrated in Fig. 3. The impacts measured were classified by visual observation as the IS hitting either the wood bottom first, cushioned by hitting a bell pepper first, or cushioned by hitting a picker's arm.

Note that during the transfer to the wooden bins, a large concentration of impacts were below the pepper damage threshold and grouped along the cushioned line. These impacts would not be of concern for pepper bruising. The impacts of concern are those above the pepper damage threshold. Most of these occurred when the IS hit the wood bottom. There are three data points for the IS impacting a soft surface (either a pepper or a picker's arm).

When the handpicked peppers are emptied from the worker's pail to the pallet bin, care should be taken that the peppers are not dumped from the top of the bin onto the hard bottom. Rather, some effort needs to be made to cushion the fall of the peppers, or to gently empty the pail onto the bottom of the bin or onto peppers.

The results for the different transfer points in the packing line are illustrated in Fig. 4. Many of the impacts are grouped below the pepper damage threshold and tend to be partially cushioned, as indicated by their location

Fig. 3. Emptying bell peppers into a wooden tote box; the steel line is for the instrumented sphere (IS) dropped onto a steel surface from a variety of heights (Brook, 1993); the cushioned line is for the IS dropped onto a cushioned surface from a variety of heights (Brook, 1993); the pepper damage threshold line was estimated from University of Florida data (Sargent et al., 1991).

between the steel and cushioned lines. The potentially damaging impacts are those that are above the pepper damage threshold. Impacts above the damage threshold are directly related to inadequate cushioning, excessive ramp angles, or excessive drops on the grading line equipment.

A pegged belt conveyed the IS from the bottom of the dump hopper and dropped it 7 inches (18 cm) onto a conveyor belting covered steel ramp, ≈4 inches (10 cm) in length transfer 1); the IS rolled down the ramp to the washing brushes. The IS measured several potentially damaging impacts during this transfer. About one half of the data points (upward pointing triangles) were above the pepper damage threshold and therefore would have resulted in a bruise. The addition of ramp cushioning (Fig. 5) would greatly reduce pepper damage. Reducing the speed of the peppers entering the washer by using hanging drapes or other means would also help reduce the damage potential for that transfer (see Fig. 6).

As the IS left the washer, it dropped ≈2 inches (5 cm) onto a steel ramp and rolled onto PVC inspection rollers (transfer 2). Only two data points (downward pointing triangles) were above the pepper damage threshold (Fig. 4). While this was not an area of great concern, the addition of cushioning (Fig. 5) and flaps or a curtain (Fig. 6) would reduce pepper damage.

As the IS left the inspection rollers, it dropped ≈3 inches (8 cm) onto a steel ramp (20% slope ramp) and rolled onto sponge donut rolls of the waxer (transfer 3). Only two data points (X symbol)

for this transfer were above the pepper damage threshold (Fig. 4). While this transition would not be of great concern for pepper bruising, the use of cushioning (Fig. 5) and flaps or a curtain (Fig. 6) would reduce pepper damage.

As the IS left the waxer it rolled down another 20% slope ramp to the diverging-roll sizer (transfer 4). The maximum drop to the sizing rollers was ≈10 inches (25 cm). About one half of the data points (plus symbol) were above the damage threshold (Fig. 4). Use of cushioning (Fig. 5) and flaps or a curtain (Fig. 6) would reduce pepper damage.

When the IS dropped from the sizing rolls, it sometimes impacted on the divider tarp and then fell ≈7 inches (18 cm) to the conveyor underneath the rolls (transfer 5; diamond symbol in Fig. 4). Other times, the IS fell ≈13 inches (33 cm) to the conveyor underneath the rolls (transfer 6; box symbol in Fig. 4). Underneath the conveyor belt was a solid metal bottom.

For the impacts on the divider

Fig. 4. Impacts measured by the instrumented sphere (IS) on a bell pepper packing line; the steel line is for the IS dropped onto a steel surface from a variety of heights (Brook, 1993); the cushioned line is for the IS dropped onto a cushioned surface from a variety of heights (Brook, 1993); the pepper damage threshold line was estimated from University of Florida data (Sargent et al., 1991).

Fig. 5. Ramps (and cushioned ramps) can be used to reduce effective drop height when the pepper must transfer from one piece of equipment to another at a lower height.

Fig. 6. Prevent produce acceleration down ramps by using hanging curtains or flaps.

Fig. 7. Remove metal support under belt where produce impacts lower conveyor.

tarp, some of the data points above the pepper damage threshold were when the IS hit the steel pipe holding the tarp. This is an area of concern that should be padded to cushion impacts.

The cross conveyor had several impacts above the pepper damage threshold. There was a high potential for damaging impacts to occur to peppers dropping from the sizer rolls directly onto the cross conveyor belt. There was not an opportunity to add padding to help cushion these impacts. To reduce the damage poten-

tial, the solid metal support where the peppers impact the conveyor must be removed (Fig. 7).

Dropping the IS 4 inches (10 cm) onto hand held peppers resulted in 67% of the impacts causing a slight external bruise but all resulted in internal cracking. At the 6 inch (15 cm) drop height, 50% had extensive external bruising and 75% had some internal cracking. At the 8 inch (20 cm) drop height, all had both external bruising and internal cracking. While the weight of the IS was greater than that of most peppers, these data illustrate the potential for pepper damage to occur at relatively small drop heights. Pepper drop height should be less than 4 inch (10 cm) on a hard surface. This is comparable to the results of Florida research (Sargent et al., 1991).

Related issues for reducing bell pepper bruising

Florida researchers have evaluated bruising issues for bell peppers for several years (Brecht and Sargent, 1995; Sargent et al., 1991, 1992). The stem-end shoulder was identified as the most susceptible area of the pepper for bruising. The worst bruises occur when the peppers fall or are propelled from conveyors onto uncushioned metal plates or rollers. Ten percent of peppers dropped 3 inches (8 cm) onto a hard surface are likely to bruise; providing appropriate cushioning can reduce bruising to zero if dropped from 3 inches (8 cm) or to 10% bruised peppers if dropped 8 inches (20 cm) (Sargent et al., 1991).

Field growth conditions can increase bruising susceptibility; excessive nitrogen fertilization and high temperatures [above 80 °F (26.5 °C)] during fruit growth can result in peppers being more susceptible to bruising. Different pepper varieties have different bruise susceptibilities under the same conditions (Brecht and Sargent, 1995).

Cold and wet conditions at harvest aggravate pepper bruising; peppers colder than 60 °F (15.5 °C) bruise easier than warmer ones; a 1% loss in fresh weight significantly reduces bruising susceptibility (Brecht and Sargent, 1995).

The major problems on packing lines are excessive height differences between line components, lack of control of rolling velocity, and lack of cushioning on hard surfaces (Guyer et al., 1991; Giacchetti, 1996). Keep line fill volume as full as possible so that peppers walk down all ramps preventing peppers accelerating and bruising when they stop abruptly.

The severity of impact and bruising at each transfer depends on the energy involved in the impact and the surface being impacted. The impact energy results from the weight of the pepper and the height difference in the transfer. A reduced height difference results in a lower impact energy, with less bruising and mechanical injury.

Cushioning on impacted surface catches the produce and absorbs the impact energy through a greater surface contact area, and, in turn, decreases the stress and damage to the produce. Adding cushioning material on transfer ramps is also beneficial, as it cushions the small impacts that occur during rolling and reduces the speed of the produce, and, thus the impact energy.

- Minimize height differences between pieces of equipment; use cushioned ramps to help reduce drop height (Fig. 5).
- Reduce the pepper velocity with overhead flaps, curtains or blankets (Fig. 6).
- Adequately cushion all locations where peppers impact a hard surface; replace cushioning as wear occurs and resiliency changes.
- Time or synchronize all components and transfers to achieve a constant, full-line flow of peppers over the entire packing line (volume of peppers = capacity of packing line).
- All transfer points involving conveyor belts should be evaluated for the support surface under the belt at the point of pepper impact. Eliminate solid support metal or rollers under conveyor belts where peppers impact belts (Fig. 7).
- Where possible, adjustments should be made so that the head

pulley is not part of the pepper impact area.

- Regularly inspect the receiving hoppers, conveyors, side rails, areas of impact, staplers, etc. to check for any sharp edges, loosened hardware, and equipment wear or misadjustment, and inspect cushioning for worn, loose or hardened material.
- Bell peppers are frequently packed into corrugated fiberboard shipping boxes. Care must be taken with maintenance of the box staplers. Typically, packing houses staple box flaps prior to being filled. We observed faulty or worn staplers that did not crimp the staples. This resulted in a staple puncture on two to four bell peppers in each box. This represented 5% to 10% of the peppers in the box. Substitution with plastic taping or banding systems would reduce this damage.
- Educate workers about the significance of bruising that occurs during the harvest and postharvest handling of bell peppers.

Conclusions

Cushion the fall of the peppers from the worker's pail to the pallet bin or gently empty the pail onto the bottom of the bin or onto peppers.

All locations where peppers impact a hard surface should be cushioned. The drop height for peppers should be limited to 3 inches (8 cm) or less on a hard surface and <8 inches (20 cm) on a cushioned surface.

Cushioned ramps and hanging flaps or curtains should be used to help reduce acceleration and drop height at transfer points between pieces of equipment.

The diverging roll-sizer had the greatest potential for damage for the

line evaluated. Adding cushioning to hard surfaces and removing the metal support from under the cross-conveyor will reduce pepper damage.

The speed of all components in the system should be checked and adjusted to achieve a full flow of peppers.

The Instrumented Sphere is a tool that can help to identify potentially damaging impacts in bell pepper harvest operations and on packing lines.

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